



- “Free Flight with Airborne Separation will result in an uncontrolled, dangerous jungle without a firm central controlling element such as ATC.”
- “Pilots haven’t got the time, the training nor the mental resources available to function as ATC on top of flying the aircraft.”



# *Overview of NLR Free Flight project '97 - '99*



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# *Free Flight goals*

- **Reduce Costs via user preferred routing**
  - Horizontally
    - direct to destination
    - optimum speed
  - Vertically
    - optimum level
    - cruise climb
- **More capacity**



## *Operational concept*

- **No ATC**
  - Probe the limits for HF problems
- **All aircraft fully equipped**
  - Linked via e.g. ADS-B
  - EFIS-CDTI
- **Full user preferred routing**
  - Direct routing
  - Optimal cruise altitude



## 1997: Three sub-studies:

- CONCEPTUAL DESIGN

*Tool: Traffic Manager: Off-line simulations*

- Find a suitable base-line concept

- SAFETY ANALYSIS

*Tool: TOPAZ (Traffic Organization and Perturbation AnalyZer)*

- Compare safety of Airborne Separation with safety ATC

- HUMAN-IN-THE-LOOP EXPERIMENT phase I

*Tool: Research Flight Simulator*

- Validation of concept with Man-in-the-Loop
- Human Machine Interface Validation



## 1998: Four sub-studies:

- CONFLICT GEOMETRY STUDY

*Tool: Traffic Manager: Off-line simulations*

- Check critical geometries: wall, etc.

- AVIONICS STUDY

*Literature survey*

- Check requirements for RNP, ADS-B etc.

- COST-BENEFITS & PERFORMANCE

*Tool: Traffic Manager: Off-line simulations*

- Costs of conflict resolution

- HUMAN-IN-THE-LOOP EXPERIMENT phase II

*Tool: Research Flight Simulator*

- Validation of PredASAS & mixed equipage



## 1999: *Three activities:*

- **DISSEMINATION**

*Conferences, Web site, Contract report, RTCA,  
ICAO*

- Explain results obtained so far

- **DATA ANALYSIS phase II trials**

- Analysing data generated in phase II trials

- **DEVELOPMENT HUMAN INTERACTION EXP**

*Tool: Traffic Manager, Freesim & internet*

- Effect of competition



# Traffic & Experiment Manager



# *Result Traffic Manager simulations*



- **Resolution advisories**

Several concepts studied:

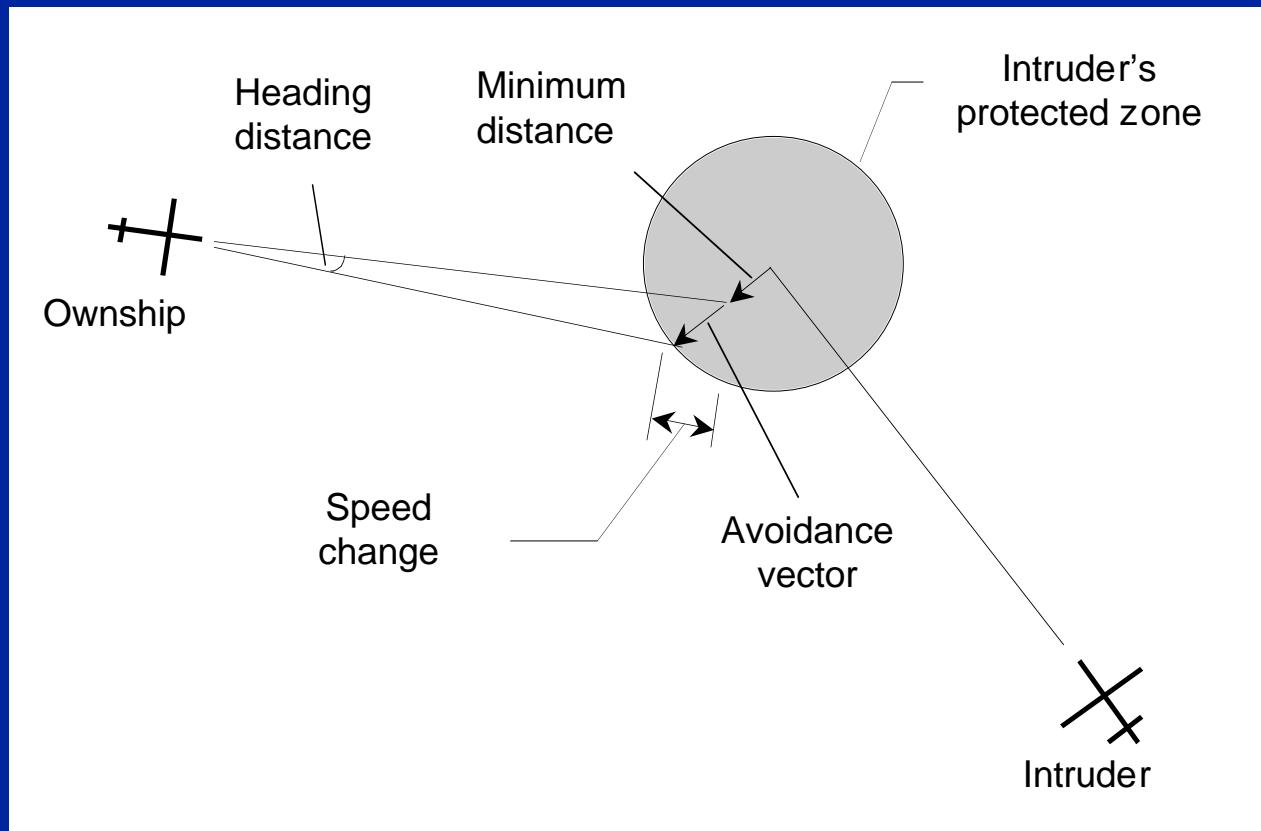
- Altitude step
- Cross product of speed vectors
- Extended VFR rules (not implemented)
- Variations of TCAS manoeuvres
- Voltage potential

- **Co-operative manoeuvring vs. priority**

- **Minimal bandwidth/HF: no intent in Conflict Detection**



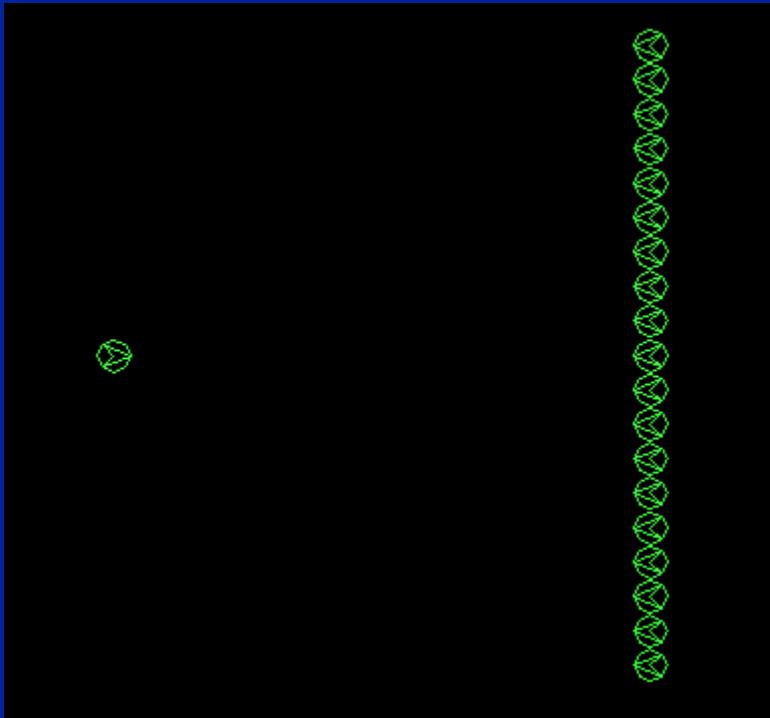
# Conflict Detection & Resolution



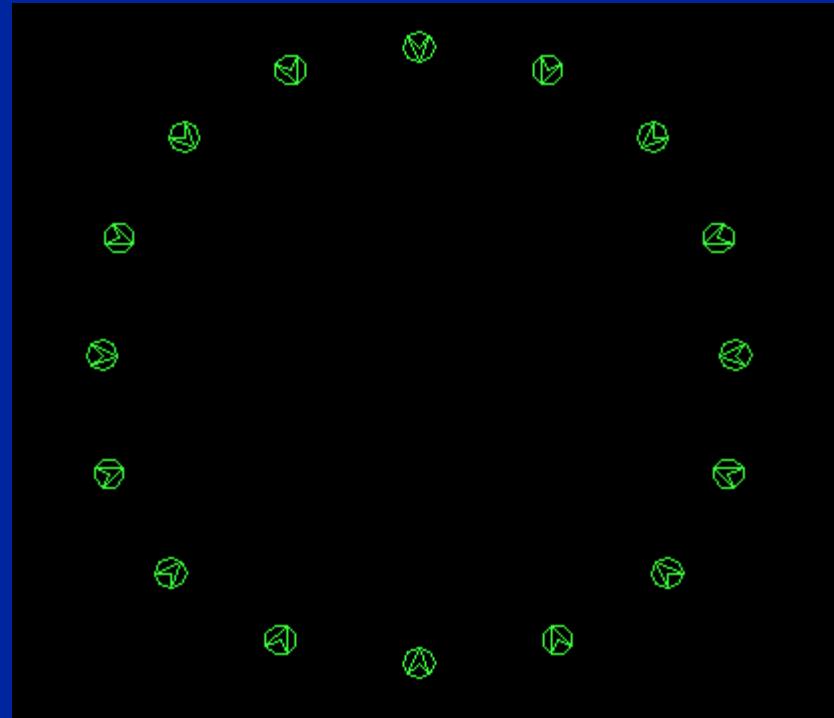


## Complex Conflict geometries

- ‘Wall’ scenarios, ‘super conflict’ ( $n = 4,8,10,12,16$ ) and ‘crossing the street’



Horizontal wall scenario



Super conflict  $n=16$  scenario



## **Traffic Symbol added to ND**

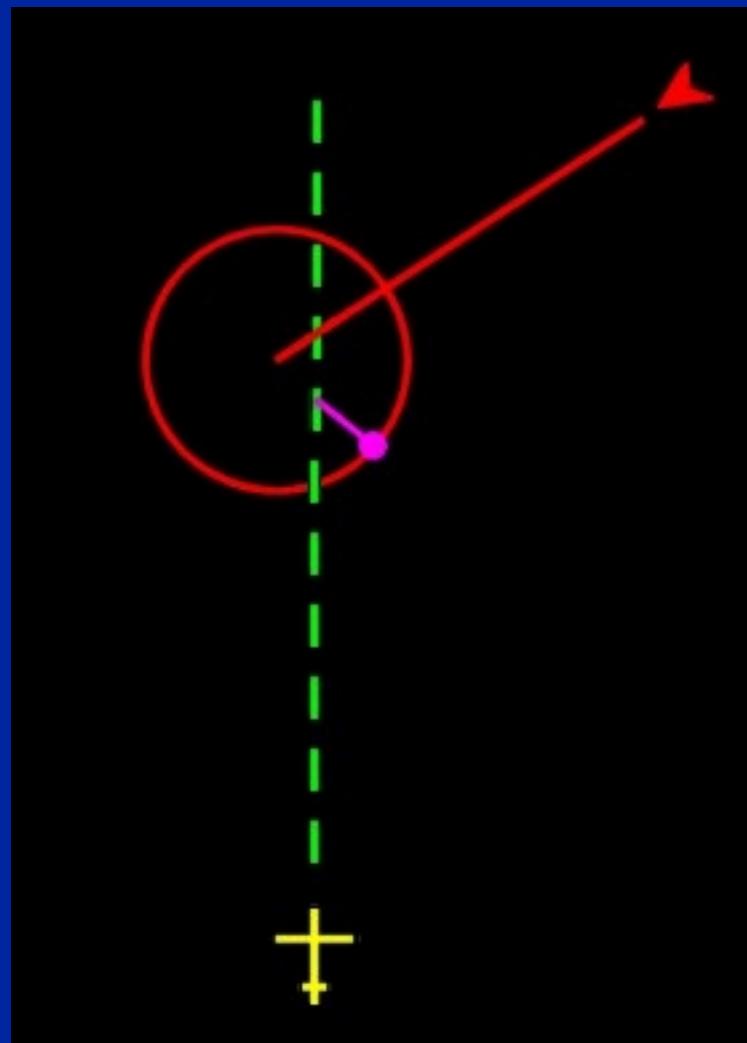
- Symbology on Navigation display based on data available via ADS-B
- Track indicated with arrow shaped symbol instead of track line to avoid clutter
- Label text selectable with de-clutter switches
- Call sign added to label of traffic symbol for inter-traffic and crew communication





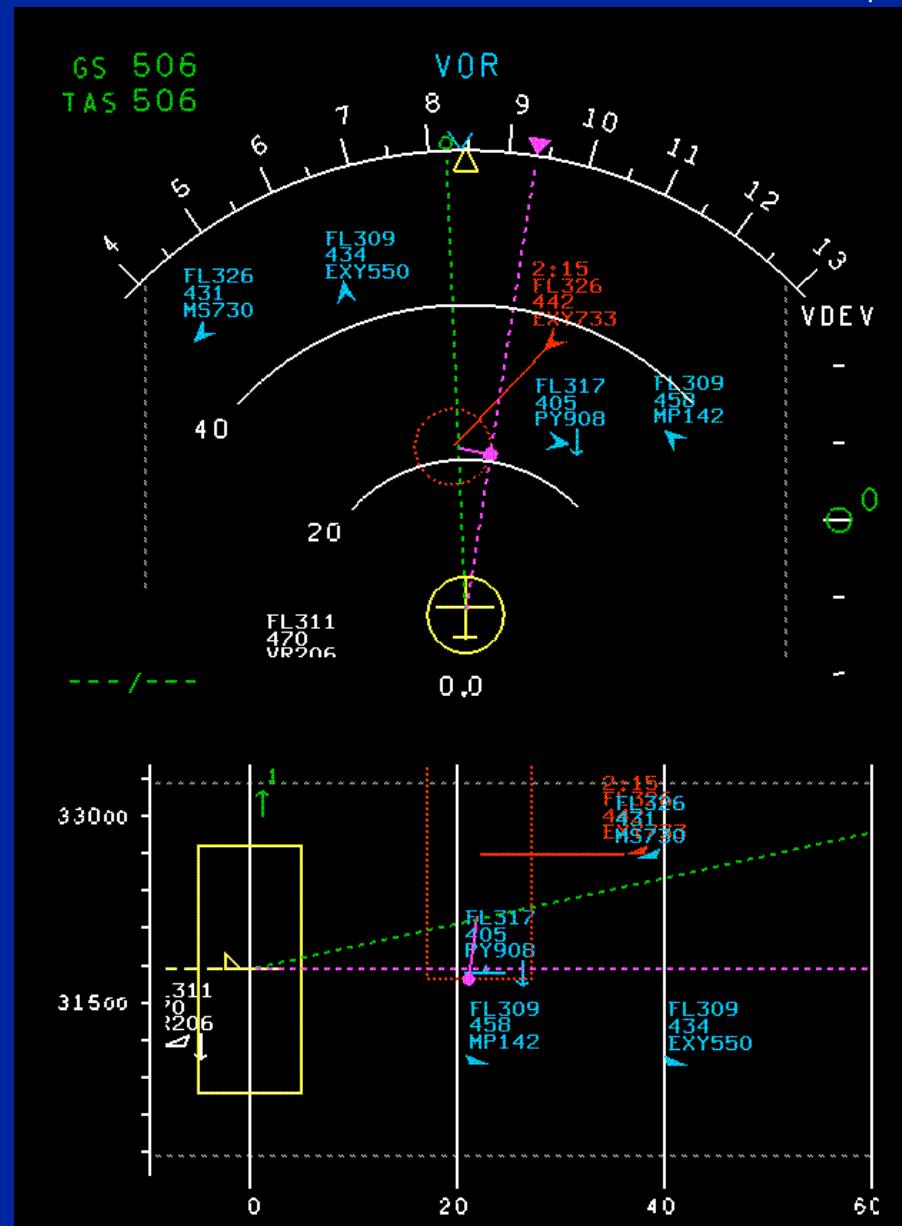
# ***Conflict Detection & Resolution***

- Symbology based on resolution algorithm
- Provides insight into resolution
- Colour indicates urgency:  
Amber = 3 - 5 min  
Red = 0 - 3 min  
(time to loss of separation)



# Navigation Display

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National Aerospace Laboratory NLR

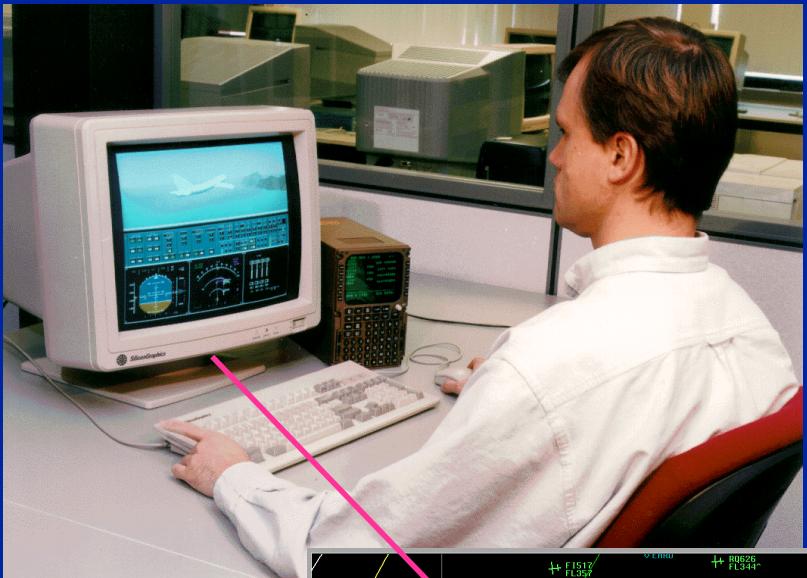


# Human-in-the-loop 97 Simulation Configuration

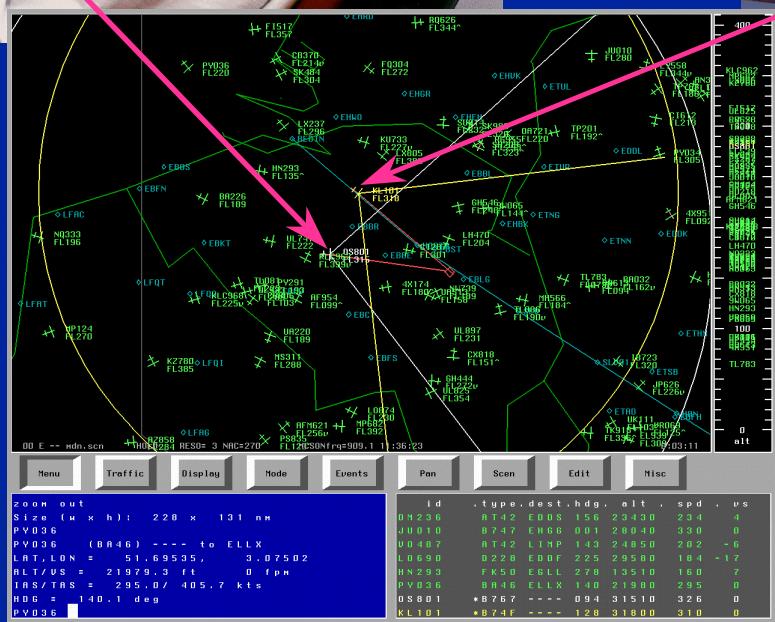
National Lucht- en Ruimtevaartlaboratorium  
National Aerospace Laboratory NLR



RFS



AIRSIM



TEM  
(TMX)



CXXX-15A



## ***Human-in-the-Loop experiment 97*** ***Hypotheses***

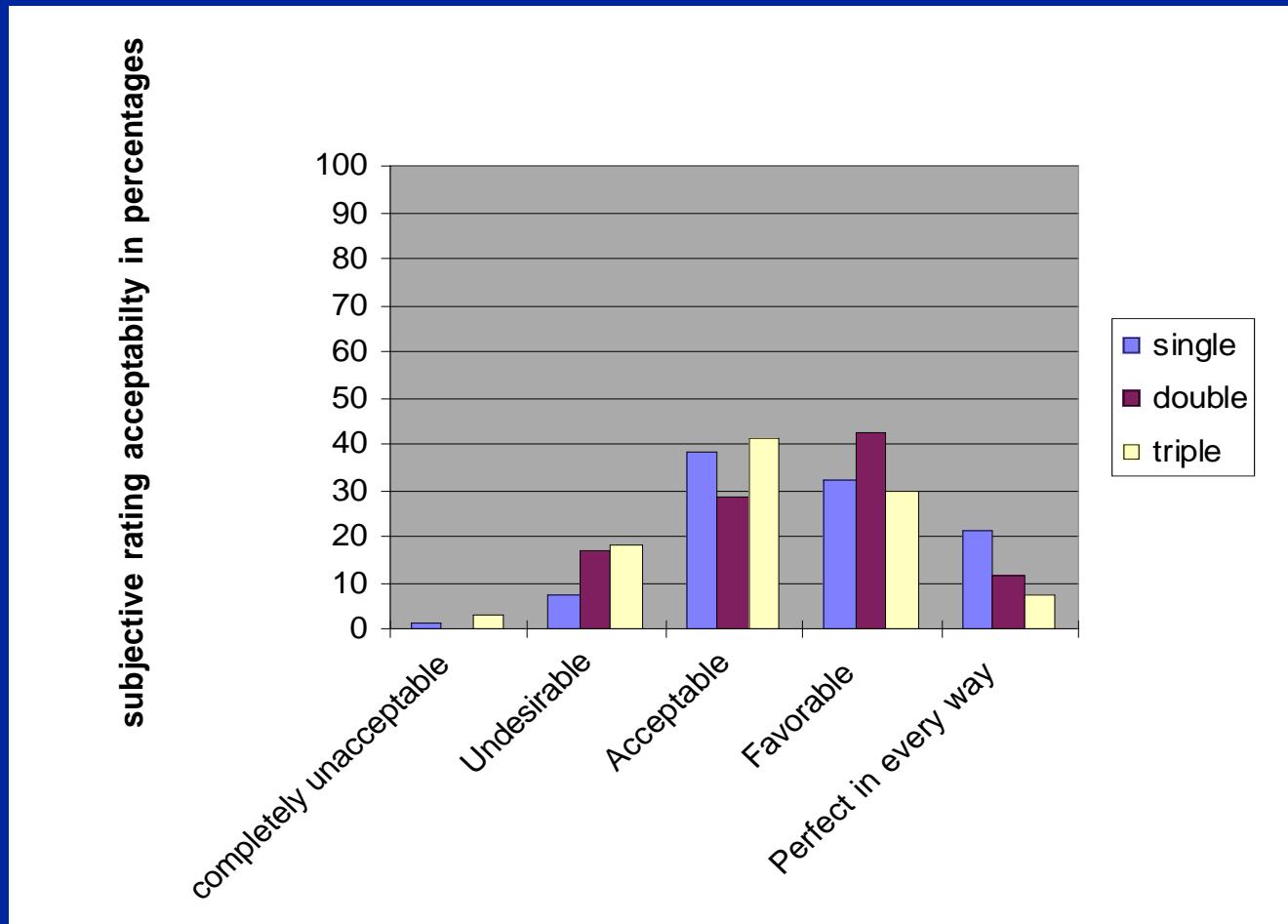
**First explorative HF experiment, so probably  
using ‘simple’ Mk 1 system would yield:**

- **Less than acceptable**
- **Subjectively less safe**
- **More workload**

**Result: HMI problem areas**

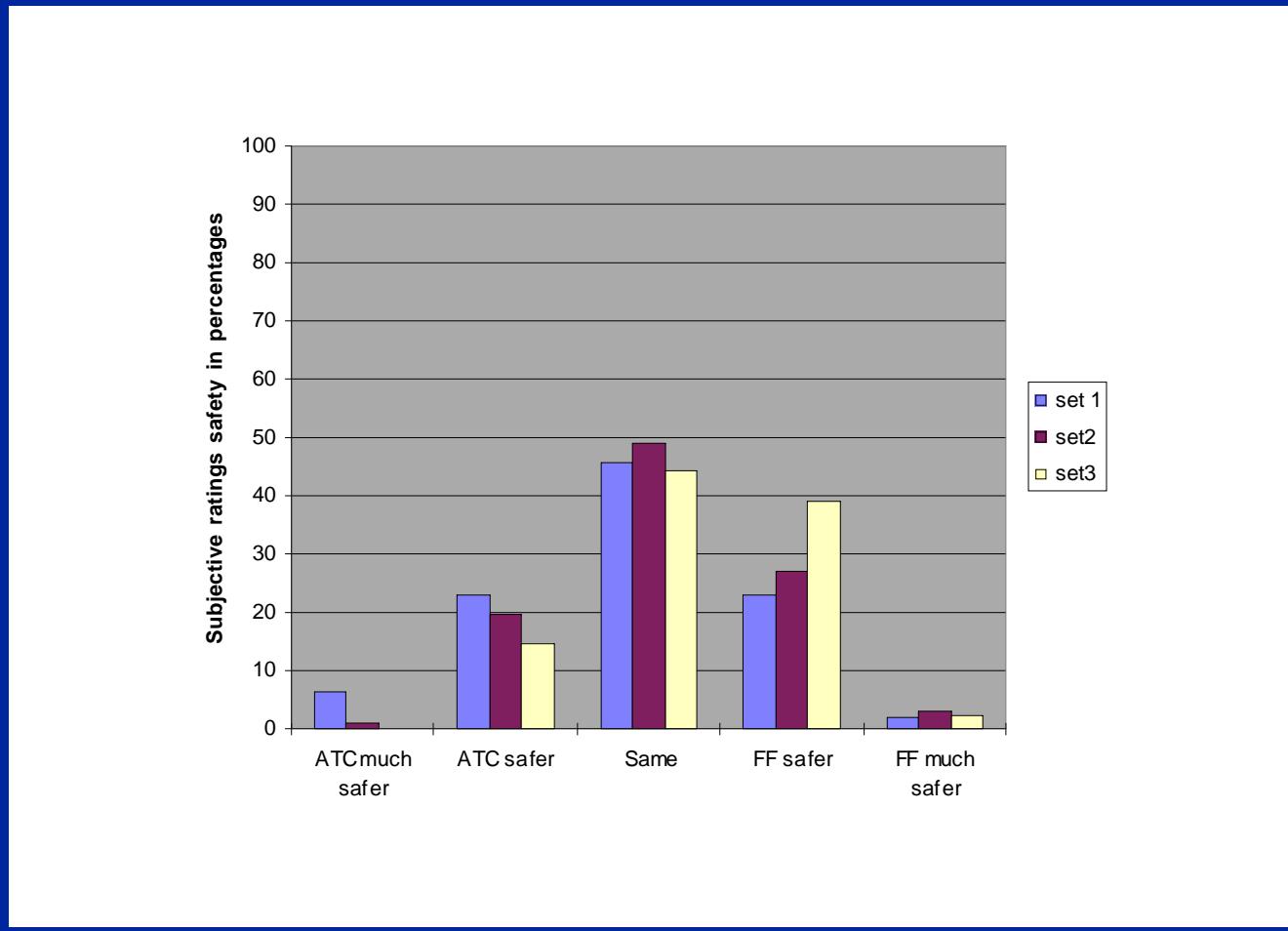
# ***Human-in-the-Loop experiment 97***

## ***Results - Acceptability***



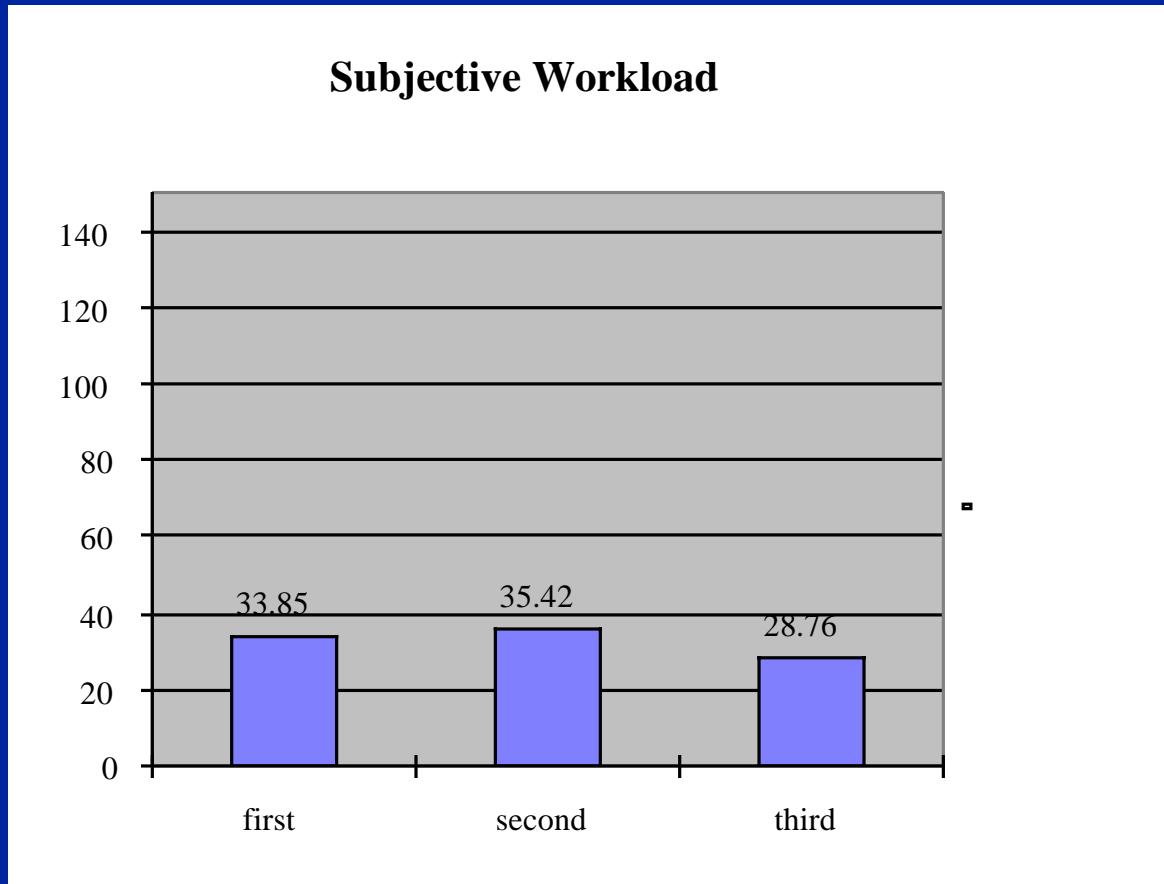
# *Human-in-the-Loop experiment 97*

## *Results- Subjective Safety*



# **Human-in-the-Loop experiment 97**

## **Results**





# ***Task comparison Controlled vs. Free Flight***



*Controlled Flight*



*Free Flight*



## ***Human-in-the-loop experiment 98***

- **Goals**

- study effect of Predictive ASAS (conflict prevention)
- study the transition to Free Flight Airspace (in space)
- study the transition towards Free Flight in time

- **Starting points:**

- equipping aircraft should be immediately beneficial to the airlines
- equipping should be economy driven in stead of mandatory
- benefit the equipped aircraft, without excluding the unequipped aircraft

## ***Human-in-the-loop experiment 98***



- Three ATM operational scenarios with Free Flight elements defined, implemented and tested:
  - Flight Level
  - Protected Airways
  - Full Mix
- Experiment matrix
  - Traffic Density - low density versus high density
  - Equipage - 25% versus 75% ASAS equipped
  - ATM operational concept - Flight Level, Protected Airways and Full Mix



## **Mixed equipage ATM procedures**

- **Flight Level division:**  
**Above FF level only equipped aircraft**
- **Protected Airways:**  
**Controlled aircraft should stay on airways and have right of way**
- **Fully Mixed:**  
**ATC uses longer 'look ahead' time, so equipped aircraft have effectively 'right of way'**

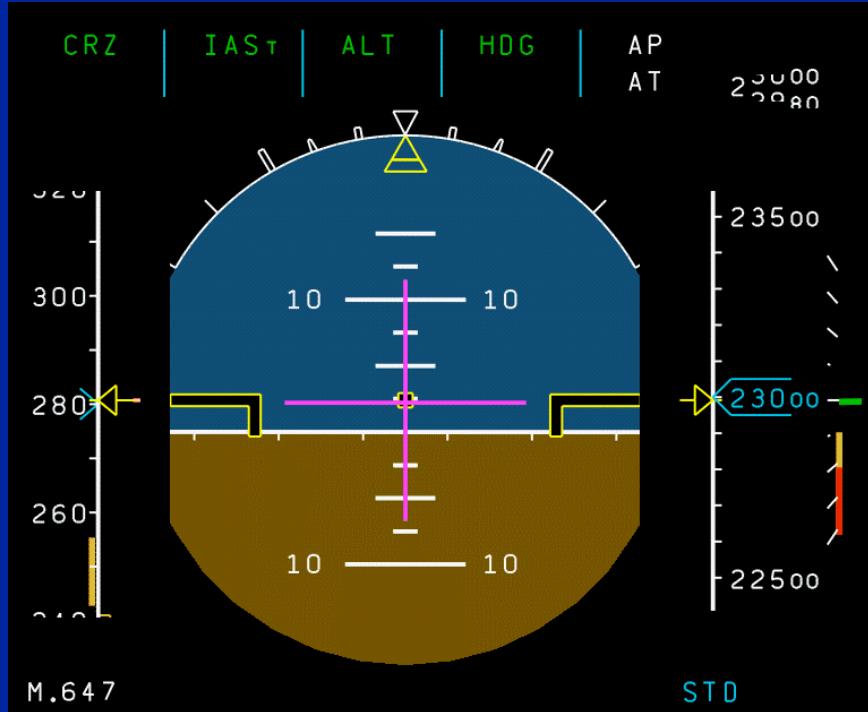


## Predictive ASAS

- **Calculates which track, vertical speed and speed selections will result in a conflict within the look ahead time**
- **Predicts a conflict by the red/amber zone moving to the actual values**
- **Indications do not require pilot actions**

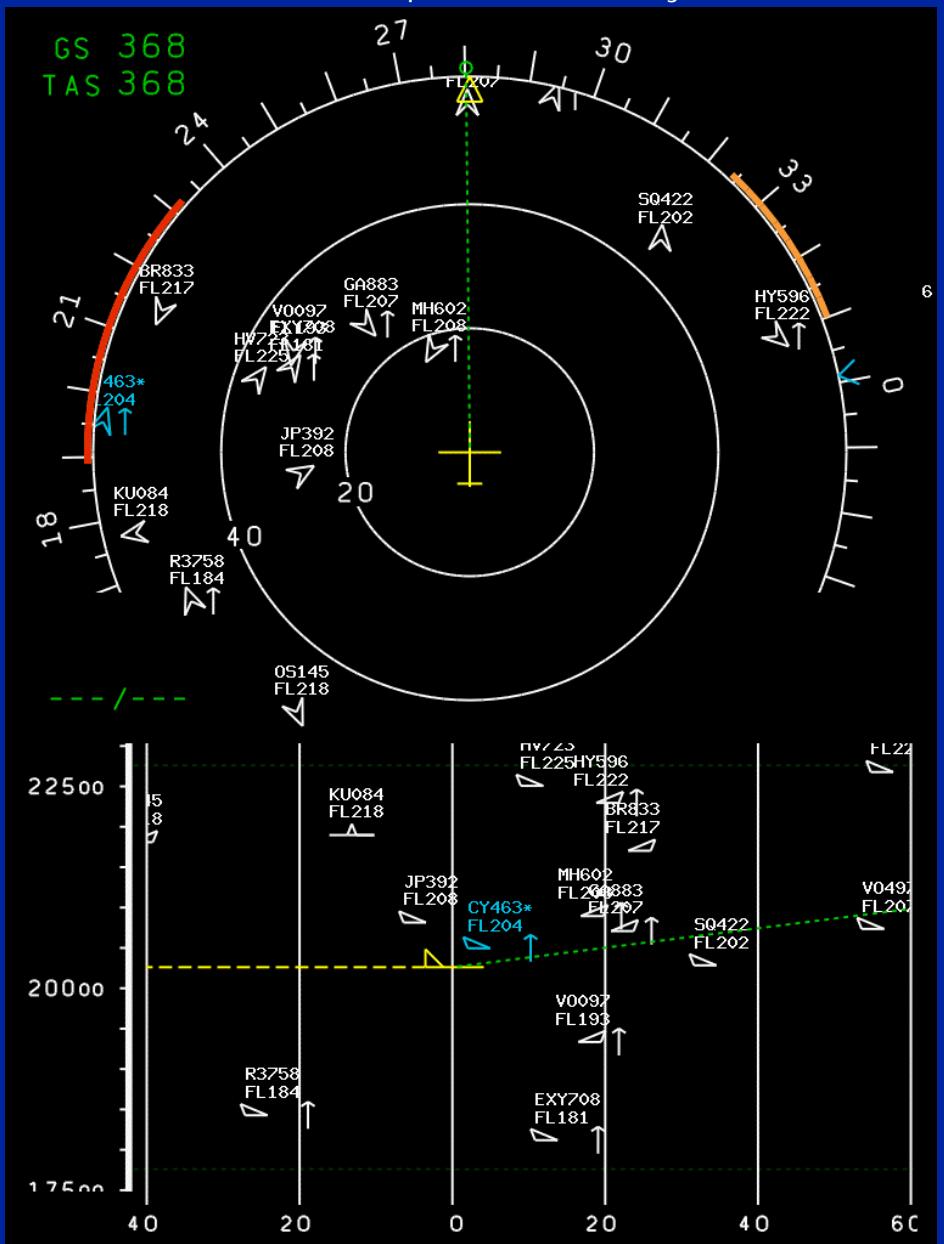
# Predictive ASAS

Nationaal Lucht- en Ruimtevaartlaboratorium  
National Aerospace Laboratory NLR



## Don't go indications:

- Track
- Vertical speed
- Speed





## **Preliminary conclusions PASAS**

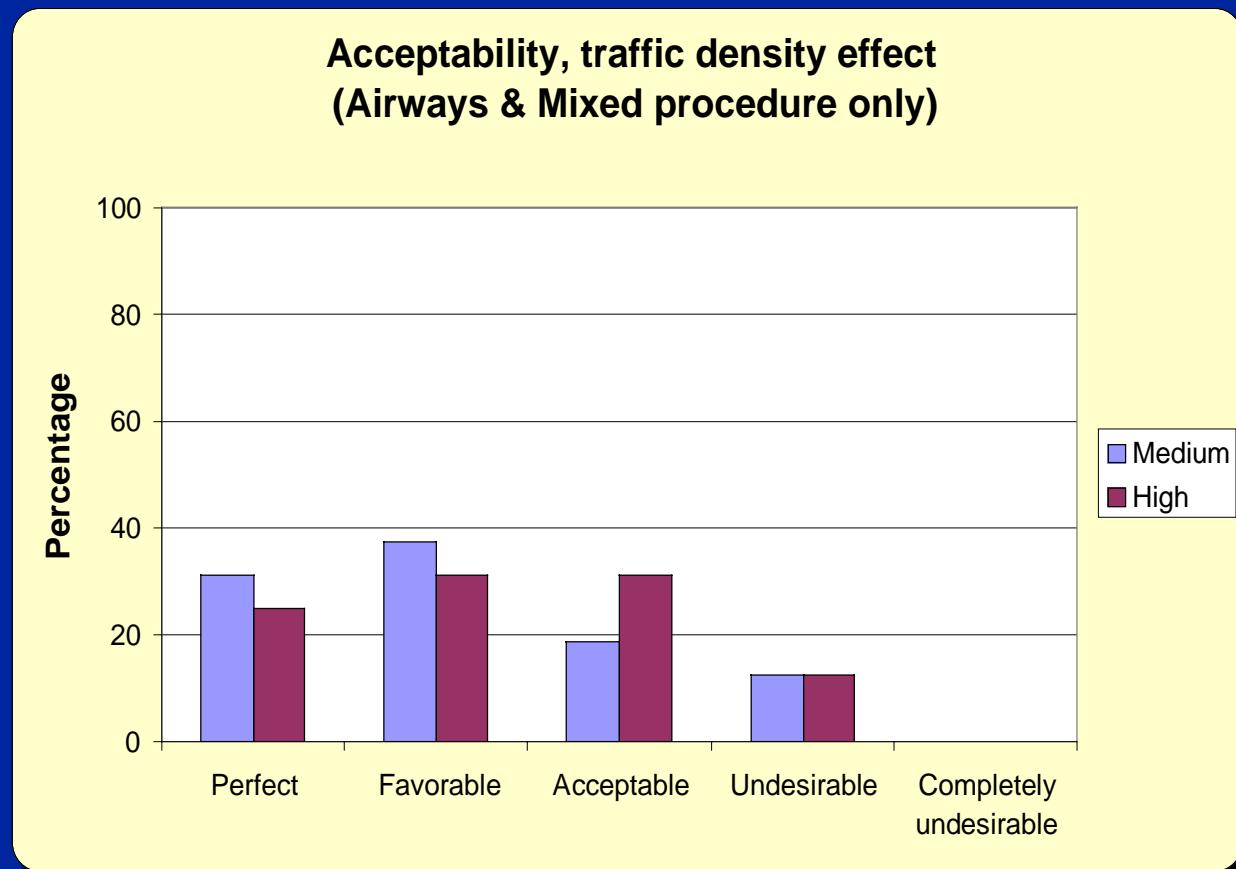
- With predictive ASAS even conflict alerts could be avoided
- Enhances situational awareness
- Might provide solution without use of intent information for Free Flight!



# ***Human in the loop experiment 98***

## ***Results: Acceptability Airborne***

- > 85% of responses indicate FF acceptable or better

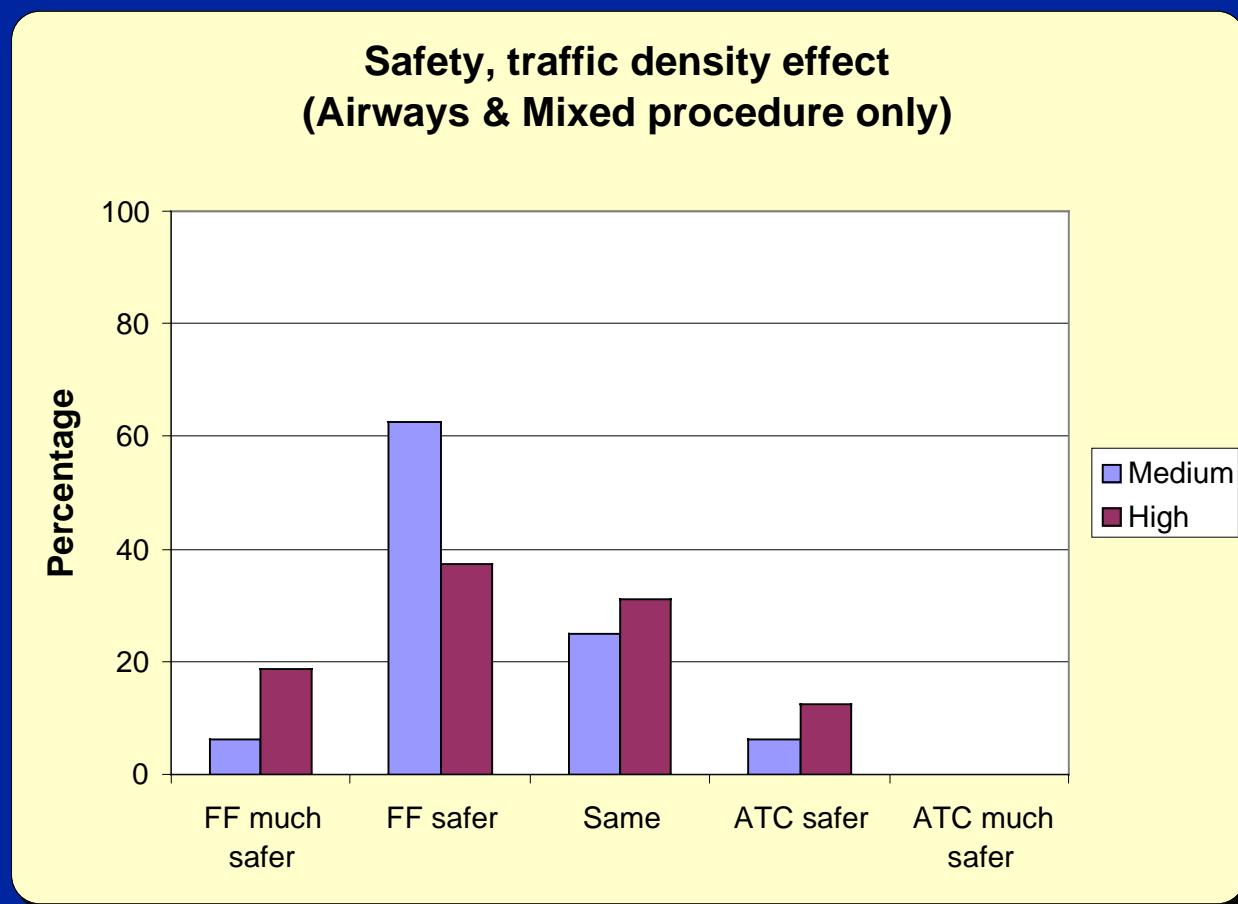




# ***Human in the loop experiment 98***

## ***Results: Subjective safety Airborne***

- > 85% of responses indicate FF as safe or safer than ATC



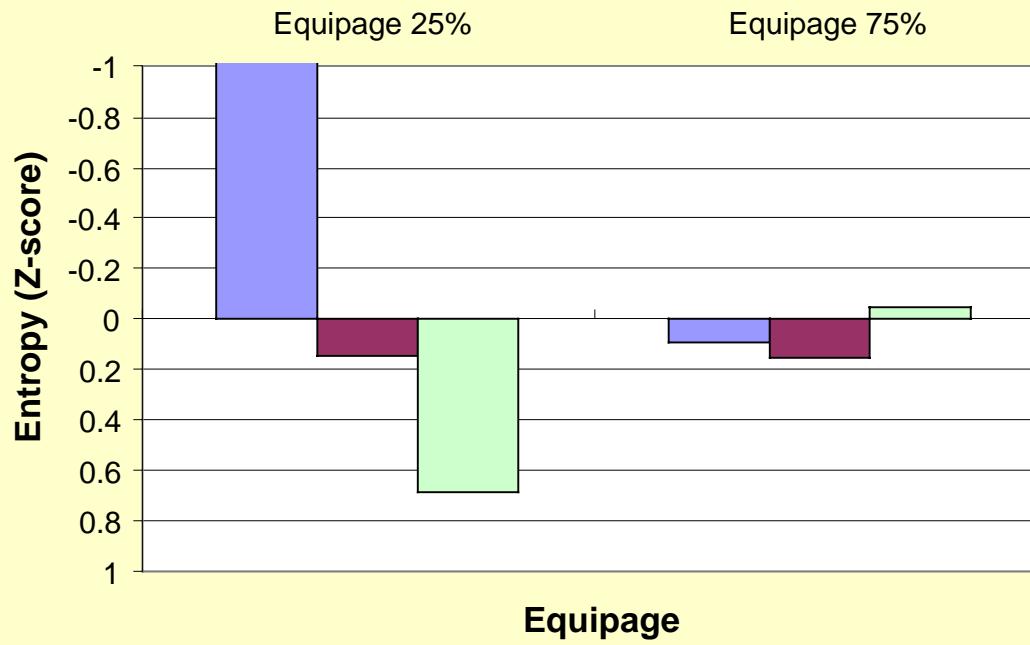


# *Human in the loop experiment 98*

## *Results: Objective workload Airborne*

Pilot objective workload  
Two-way interaction of ATC  
procedure and equipage ( $p<0.089$ )  
(medium traffic density only)

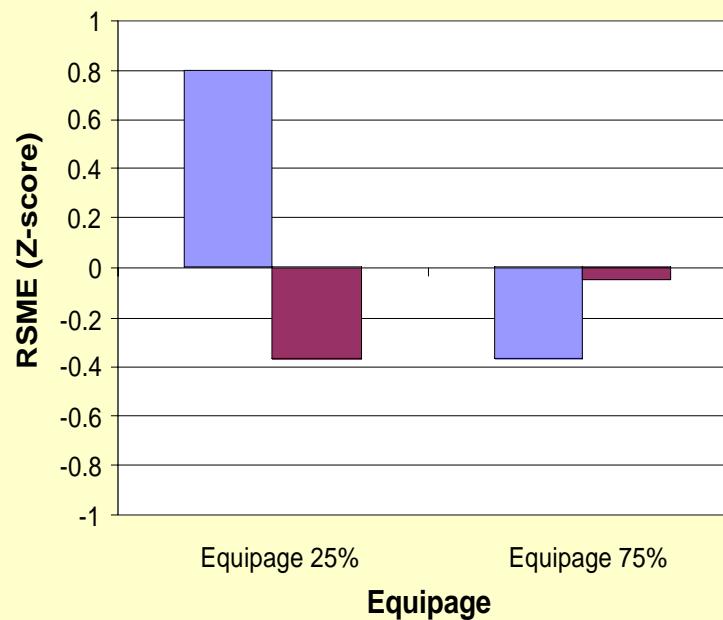
- Protected Airways
- Full Mix
- Flight Level



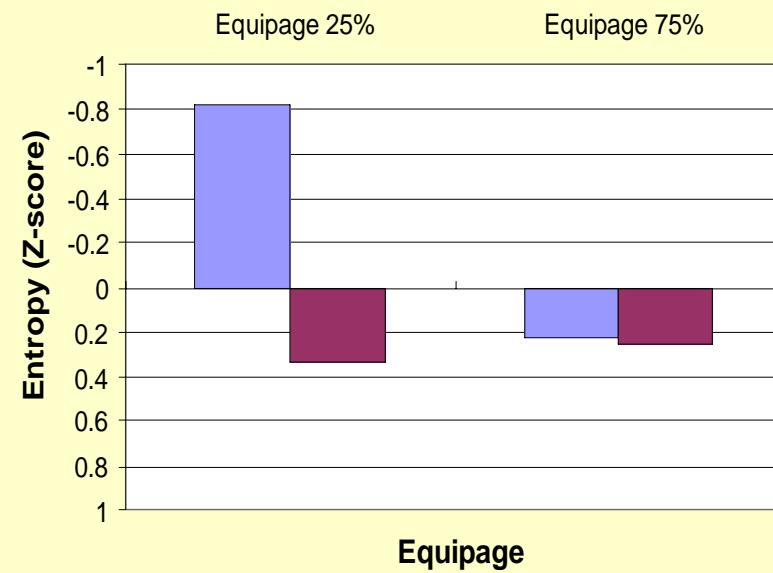


# 1998 Human-in-the-loop Results: Workload Airborne comparison

Pilot subjective workload  
Two-way interaction of ATC  
procedure and equipage ( $p<0.076$ )



Pilot objective workload  
Two-way interaction of ATC  
procedure and equipage ( $p<0.048$ )





## 1998 Human-in-the-loop Conclusions

- **The future ATM design has to be chosen very carefully:**
  - Full Mixed ATM condition is best from the pilot's perspective
  - Protected Airways ATM condition is sensitive to equipage level (transition in time)
  - Flight Level ATC condition is most optimal from Air Traffic Controller's perspective (Hilburn, Pekela)
- **The experiment matrix had to be adjusted because the flight deck crew was able to handle higher traffic densities than the ground controller**



## ***Overall Conclusions***

- The feasibility of Free Flight with Airborne Separation Assurance could not be refuted, based on 7 NLR studies on Free Flight
  - The flight deck crew was able to handle much higher traffic densities than the ground controller (distributed versus centrally organized nature)
- Free Flight might be a solution for current and future airspace capacity problems

# ***Current men-in-the-loop experiment: human interaction experiment***



- Logging into Traffic Manager via internet using downloadable FreeSim flight simulation program





## ***Current & future activities: 2000+***

- **HUMAN INTERACTION EXPERIMENT**  
Check web site
- **PHASE III FLIGHT SIMULATOR TRIALS**  
From cruise to final incl. SUA, weather, RTA  
together with Langley
- **NASA Langley Simulation Development Support**
  - Compatible sim configurations
  - Jointly develop ADS-B models
- **Continue dissemination efforts**



## ***More information***

- **NLR Free Flight web site:**  
<http://www.nlr.nl/public/hosted-sites/freeflight>  
Downloads section contains reports, presentations and demos.
- **Comprehensive report on overall studies 1997-1999**  
**Check web site for download!**
- **Demo sessions of human interaction experiment configuration will be announced on the website and NASA Langley.**